Opto-Acoustical Modules for KM3NeT

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KM3NeT

- Water-Cherenkov neutrino telescope
- Multi-cubic-kilometre instrumented volume
- Located in the Mediterranean Sea (multi-site)
- Detection Units (DUs) equipped with ~ 18 Digital Optical Modules (DOMs)
  - several ten DUs in Phase I
  - 690 DUs in Phase II
- Each DOM houses 31 PMTs
- Flexible structures require constant position monitoring
“Acoustic Positioning System”

Detection Unit

Receiver

Acoustic emitter/receiver ("Pinger")

\[ \left| \vec{r}_{\text{reception}} - \vec{r}_{\text{emission}} \right| = c_s \times (t_{\text{reception}} - t_{\text{emission}}) \]
Two different types of receiver

Opto-Acoustical Module:
- new type of sensor
- subject of this presentation

Hydrophone:
- proven technology
- various devices available
Basic concept
Integration of acoustical sensor(s) in DOMs
Optical module + Acoustical sensor = Opto-Acoustical Module (OAM)

Reference: www.km3net.org
Simplified deployment

- LOM (Launcher of Optical Modules) favours compact design without additional mechanical support structures
Current implementations of OAMs

for KM3NeT

for NEMO Phase-II

Applicable to different configurations
Lab measurements

PMTs off
PMTs on
PMTs operating at nominal voltage inject noise into system
Hydrophone and piezo on PPM-DOM
Hydrophone and piezo data from PPM-DOM

~~0.3 ms

signal [V]

time, arbitrary offset [s]
Piezo data from PPM-DOM

Acoustic emitter cycle from ANTARES emitters on anchors

Footprint of ANTARES

signal [V]

PPM-DOM

time since run start [s]

saturation

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Single signal in detail (strong signal)

Signal building up as expected
Single signal in detail (weak signal)
Angular dependence of signal strength

Signal strength vs. angle; assume piezo is at “south pole”; low statistics
Some preliminary conclusions about positioning with piezos in PPM-DOM

- Positioning under investigation, some synchronization issues between ANTARES emitters and DOM receivers. First results look promising
- S/N for pinger signals in situ better than expected
- Signal distortions observed
- For KM3NeT: different pinger signals (e.g. chirp, signals with orthogonal base)
  - Improvements compared to sine-waveform e.g.:
    - Precision of arrival time determination
    - Robustness against signal distortion
  - Tests ongoing with prototype acoustic emitter from Valencia also on ANTARES IL
**Piezo improvement and development**

**Prototype:**
- "analogue piezo"

**Final Design for KM3NeT Phase I:**
- "digital piezo"

Diagram:
- **Sensor Head**
- **Main Amplifier**
- **ADC**
- **DAQ (FPGA)**

Connections:
- External to sensor head
- Main amplifier + filter to DAQ (FPGA)
Piezo improvement and development

- "analogue piezo": current system designed for low power dissipation: ~ 0.1 W (w/o ADC)
- Hope that with better shielding noise can be suppressed (PPM-DU)
- “digital piezo”: foreseen for KM3NeT Phase I
  digital piezo will be a major overhaul:
  Improvements with analog piezo will not help for the digital piezo
  estimated power dissipation ~ 0.5 W
Summary and outlook

- Positioning with piezo in PPM-DOM is possible, signals are as expected
- Some features intrinsic to piezo-in-sphere observed: superposition, angular dependence
- Investigation of the absolut precision (to be done)
- Design of digital piezo kicked off

- possible application to acoustic particle detection
Acoustic particle detection

Deep sea

Hydrophone array
(ca. 100/km$^3$, >100 km$^3$)

Sonic wave

Particle cascade
(10 m x 10 cm)
Signal generation

Bipolar pressure pulse detectable with acoustical sensor in OAM studies on acoustic particle detection are possible
Thank you for your attention!